Electricity

Electricity consumption nearly doubles in the IEO2005 projection period. The emerging economies of Asia are expected to lead the increase in world electricity use.

The *International Energy Outlook 2005 (IEO2005)* reference case projects that world net electricity consumption will nearly double over the next two decades.[10] Over the forecast period, world electricity demand is projected to grow at an average rate of 2.6 percent per year, from 14,275 billion kilowatthours in 2002 to 21,400 billion kilowatthours in 2015 and 26,018 billion kilowatthours in 2025 (Figure 58). More than one-half (59 percent) of the projected growth in demand occurs in the emerging economies, with the mature market and transitional economies accounting for 28 percent and 14 percent, respectively.

This chapter examines the future of electricity supply and demand, beginning with a discussion of regional demand projections and the trends in expansion anticipated over the next two decades. The remainder of the chapter discusses the projections for electricity generating capacity, with particular attention to how the regional fuel mix might change over the forecast period. Regional differences in fuel diversity, operating efficiencies, and ability to meet growing demand for electric power are reviewed.

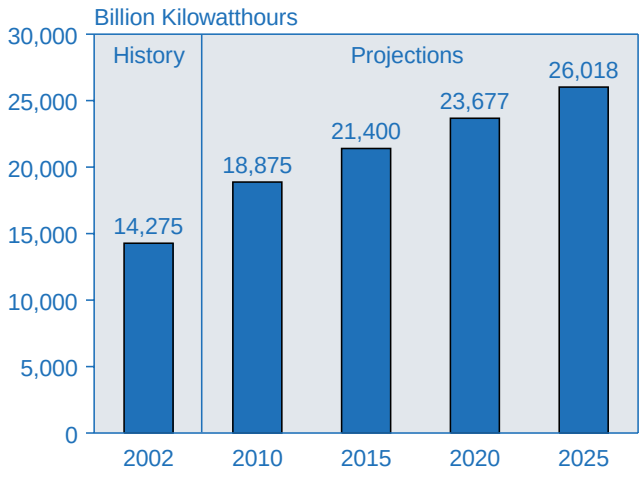
Net Electricity Consumption

Growth in net electricity consumption is expected to be most rapid among the emerging economies of the world, with annual average growth of 4.0 percent from 2002 to 2025 (Figure 59). In contrast, electricity demand is projected to increase by an average of 1.5 percent per year in the mature market economies and an average of 3.1 percent per year in the transitional economies of Eastern Europe and the former Soviet Union (EE/FSU). On an absolute quantity basis, China and the United States lead the projected growth in net electricity consumption, adding 2,803 and 1,819 billion kilowatthours over the 23-year forecast to their respective annual net consumption levels.

Mature Market Economies

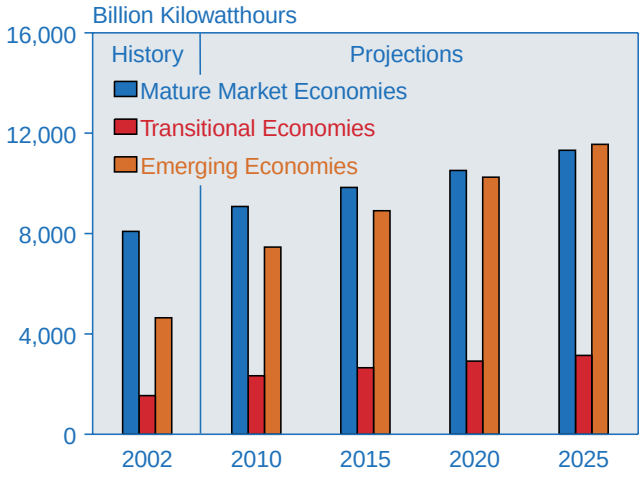
Electricity use in the mature market economies is expected to increase more slowly than in the emerging and transitional economies, averaging 1.5 percent per year in the *IEO2005* reference case over the projection period. In the mature market economies, the electricity

Figure 58. World Net Electricity Consumption, 2002-2025



Sources: **2002:** Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2005).

Figure 59. World Net Electricity Consumption by Region, 2002-2025



Sources: **2002:** Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2005).

[10] In *IEO2005*, "net electricity consumption" includes both electricity and heat produced for sale to the grid. It does not include electricity generated on site at industrial facilities.

sector is well established, and equipment efficiency gains are expected to temper the growth in electricity demand.

Although parts of the United States still have excess natural-gas-fired electricity capacity that was installed during the boom in construction between 2000 and 2004, strong economic growth throughout the country will require the development of additional generation capacity. Electricity demand in the United States is projected to increase from 3,651 billion kilowatthours in 2002 to 5,470 billion kilowatthours in 2025. Demand growth is expected to be particularly strong in the commercial sector, averaging 2.4 percent per year. Rapid additions to commercial floorspace, the continuing penetration of new telecommunications technologies and medical imaging equipment, and increased use of office equipment are projected to offset efficiency gains for electric equipment in the sector. In the industrial and residential sectors electricity consumption is expected to grow at more moderate rates, averaging 1.3 percent per year and 1.6 percent per year, respectively.

Net electricity consumption in Western Europe is projected to increase in the *IEO2005* reference case from 2,556 billion kilowatthours in 2002 to 3,072 billion kilowatthours in 2025. Electricity demand growth in the region will, in part, be influenced by the progress it makes in liberalizing its electric power markets. Western Europe's drive to reduce cross-border barriers throughout the regional economy is expected to increase competition in its electricity and natural gas markets, offsetting some of the increased costs that will result from reduced reliance on coal-fired and nuclear power plants and increased reliance on natural gas and renewables for electricity production.

All electricity customers in the European Union (EU) will have the right to choose their suppliers by July 2007. Furthermore, in 2004 new EU directives entered into force, requiring energy companies to unbundle formerly vertically integrated supply chains and mandating the establishment of uniform, well-defined regulatory bodies to increase information transparency, helping to increase competition in the electricity sector and, as a result, restrain price increases [***1***].

In addition, populations in Western Europe and Japan are expected either to remain at current levels or to decline slightly toward the end of the forecast period, and as a result it is unlikely that demand for electricity in the residential sector will increase substantially. Western Europe and Japan are expected to have the slowest growth in residential electricity consumption, averaging 0.4 and 0.6 percent per year, respectively, and in commercial electricity consumption, averaging 0.8 and 0.9 percent per year, respectively.

Transitional Economies

Electricity demand among the EE/FSU transitional economies is projected to increase at an average annual rate of 3.1 percent over the 2002-2025 period. This is higher than the 1.5-percent average annual increase over the past 30 years, mostly as a result of the precipitous drop in electricity use that followed the fall of the Soviet regime in the early 1990s. Net electricity consumption in the EE/FSU region is projected to climb from 1,544 billion kilowatthours in 2002 to 3,145 billion kilowatthours in 2025.

Many of the FSU countries are attempting to reform or liberalize their electricity sectors—for the most part, to attract much needed private and foreign investment to repair and expand aging and neglected infrastructure. In Russia, for instance, little investment was made in the 1990s to upgrade the country's electricity system, and especially its transmission and distribution infrastructure, which includes some operational transformers that date back to the 1930s [***2***]. A recent major electricity blackout in Moscow underscores the infrastructure problem. On May 25, 2005, between 2 and 4 million people were left without electricity for several hours following an explosion at a Moscow substation that had been operating for more than 40 years.

Russia's thermal generating capacity is scheduled for privatization as part of the country's electric power sector restructuring plan, with nuclear power plants remaining under state control and hydroelectric facilities placed under the control of a single state-owned company [***3***]. The state-owned Unified Energy Systems utility has created 6 wholesale power generating companies and 14 territorial generating companies to be privatized in 2005; however, the government has delayed the privatization until early 2006.

Outside Russia, the progress toward electricity sector reform has been mixed. Kazakhstan appears to be in the most advanced stage of restructuring in the region. Restructuring of the power sector in Kazakhstan began in 1995 with the unbundling of distribution, transmission, and generation functions [***4***], and by 1998, the government had privatized most of the country's generating capacity, as well as a number of distribution companies, and was allowing direct electricity sales to large end users.

Ukraine's privatization effort began in 1997, and each of the country's regional electricity distributors has been partially privatized [***5***]. Progress has been slow for a number of reasons, however. Only minor percentages have been offered to investors, and investors are required to commit to substantial, long-term investments in the electricity infrastructure. In addition, Lithuania, Azerbaijan, and Uzbekistan have started

power sector liberalization, although their progress also has been slow.

In Eastern Europe, efforts to restructure and liberalize national electricity sectors have been driven by the accession of several countries[11] to the EU. EU membership has compelled many nations of the region to reform electricity markets in order to meet EU standards. The Czech Republic plans to begin selling its 67.8-percent stake in the Ceske Energeticke Zavody generator sometime in 2006 to comply with EU rules on electricity sector liberalization [*6*], and 10 of the 12 power producers in Hungary are owned by foreign companies.

Emerging Economies

Emerging economies are projected to more than double their net electricity consumption, from 4,645 billion kilowatthours in 2002 to 11,554 billion kilowatthours in 2025. The projected growth in net electricity consumption for the emerging market economies is driven in large part by gross domestic product (GDP) and population growth assumptions (see box on page 69). GDP growth is in turn dependent on access to reliable electricity supplies.

Because of the links between reliable electricity supply, GDP growth, and living standards, many of the nations with emerging economies are attempting to increase access to reliable electricity supply. The need to increase their citizens' access to electricity has led many governments of the emerging economies to implement a variety of strategies, such as privatization to increase investment in the electricity sector, enacting government policies to encourage investment from potential foreign participants, and introducing rural electrification schemes aimed at bringing electricity to rural communities, both to improve standards of living and to increase the productivity of rural societies. The International Energy Agency has estimated that 1.6 billion people lacked access to electricity in 2002 and that, despite projected gains in electrification rates, the number of people without access to electricity will fall only slightly (to 1.4 billion in 2030), mostly as a result of continued population growth in developing countries [*7*].

As an example of the efforts being made to improve electrification, India announced plans in March 2005 to continue subsidizing electricity consumption for rural and poor households that use less than 30 kilowatthours per month. Currently, 45 percent of households in India do not have access to electricity. The new legislation has set a target of electrifying all households by 2010. As in the past, the ongoing challenge in providing electricity to the poor is paying for the electricity. Some progress has been made in reducing cross-sector subsidy burdens; however, even with commercial and industrial consumers subsidizing poor consumers, regional electricity companies still are expected to pay for some of the subsidies [*8*]. The burden of subsidies is amplified by inadequate revenue collection systems and outright theft of electricity. For example, in 2002 India's regional electricity companies lost $5.3 billion [*9*].

India's new electricity policy also places considerable emphasis on reliability. The policy "requires that within six months the Central Electricity Authority must launch its first National Electricity Plan, covering the period to 2017. Central to the plans is the provision of adequate generation capacity by 2012 based on 85 percent availability and including reserves of at least 5 percent" [*10*].

In China, news reports over the past few years have highlighted electricity generation shortfalls during periods of peak demand. To close the annual supply shortages and meet further growth in demand, China's 11th five-year plan includes plans for expanding electricity generation capacity to 570 gigawatts by 2010. In order to meet this rapid rate of expansion, roughly 8 percent annually, investments of $20 to $30 billion per year will be needed [*11*]. It appears, however, that building more power plants may not provide a complete solution to China's electric power limitations. Equally important is supplying primary fuel to the power plants and constructing transmission lines to reach electricity consumers. The Chinese State Grid Corporation estimates that investments of $10 billion per year will be needed for upgrading electricity transmission infrastructure alone [*12*].

The potential impacts of lack of electric power infrastructure on China's economy are illustrated by recent developments in the country's industrial sector. Three-quarters of the electricity consumed in China is used for manufacturing and heavy industry [*13*]. When electricity shortages occurred in the summer of 2004, some industrial production had to be cut. In 2004 Beijing shut down approximately 6,400 industrial facilities for one week and then staggered their operations for the duration of the summer to avoid consumption peaks [*14*]. It is clear that, unless the Chinese electricity infrastructure can keep pace with demand for electric power, the negative impact of electricity shortages on the industrial sector could have significant detrimental impacts on the country's economy.

Electricity Supply

To meet the world's projected electricity demand over the 2002 to 2025 forecast period, an extensive expansion of installed generating capacity will be required.

[11]The Czech Republic, Hungary, Poland, Slovakia, and Slovenia acceded to the European Union in May 2004. Bulgaria and Romania are scheduled to join in 2007.

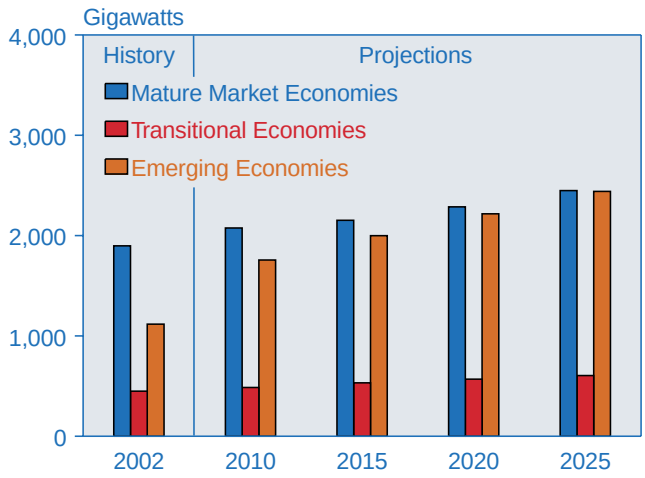
Worldwide installed electricity generating capacity is expected to grow from 3,315 gigawatts in 2002 to 5,495 gigawatts in 2025 in the *IEO2005* reference case, at a 2.2-percent average annual growth rate (Figure 60).

In *IEO2005*, "generating capacity" is defined as the hourly level of production when a power plant is operating at full capacity. Baseload generation typically operates as close to full capacity as possible. Peaking systems, such as natural gas turbines, typically operate at times of peak demand—that is, those times of the day when electricity use is at its highest. In contrast, most renewable electricity generation systems[12] cannot be relied upon to meet peak demand. Instead, renewable systems are operated whenever resources are available. Wind turbines do not operate when wind speeds are either too low or too high; hydroelectric power is vulnerable to drought; and solar systems do not operate at night. That said, even fossil fuel and nuclear power plants cannot operate at 100 percent capacity all year long. Outages for annual maintenance, as well as seasonal and daily fluctuations in demand, reduce their "operating capacity" relative to their "nameplate capacity."

The mix of primary fuels used to generate electricity has changed a great deal over the past three decades on a worldwide basis. Coal has remained the dominant fuel, although electricity generation from nuclear power increased rapidly from the 1970s through the mid-1980s, and natural-gas-fired generation has grown rapidly in the 1980s and 1990s. In contrast, in conjunction with the high world oil prices brought on by the oil price shocks after the oil embargo by the Organization of Arab Petroleum Exporting Countries (OAPEC)[13] in 1973-1974 and the Iranian Revolution in 1979, the use of oil for electricity generation has been slowing since the mid-1970s. High world oil prices encouraged switching from oil-fired generation to natural gas and nuclear power and reinforced coal's important role in world electric power generation.

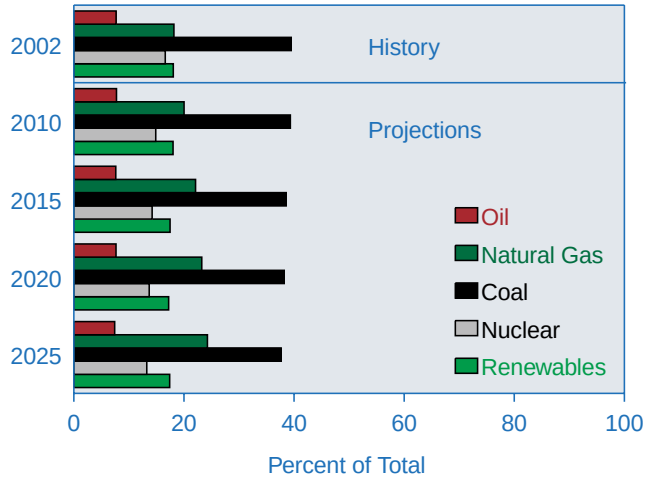
In the *IEO2005* reference case, continued increases in the use of natural gas for electricity generation are expected worldwide (Figure 61). Coal is projected to continue to retain the largest market share for electricity generation, but its importance is expected to be moderated somewhat by a rise in natural gas use. The role of nuclear power in the world's electricity markets is projected to lessen, although some new reactors are expected to be added over the forecast horizon, mostly in the emerging and transitional economies. Generation from hydropower and other renewable energy sources is projected to grow by 54 percent over the next 23 years, but their share of total electricity generation is projected to remain near the current level of 18 percent.

Figure 60. World Electricity Generation Capacity by Region, 2002-2025



Sources: **2002:** Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2005).

Figure 61. Fuel Shares of World Electricity Generation, 2002-2025



Sources: **2002:** Derived from Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2005).

[12]The generation capacity data presented in this chapter as "renewables" include hydropower, wind, geothermal, solar, and other. The data for hydropower include conventional hydro impoundment, run-of-river, and pumped storage because of the difficulty in distinguishing among the various technologies on a worldwide basis. A further challenge is accounting for distributed small-scale hydroelectricity production. Therefore, the renewable generation capacity figures may underrepresent total installed capacity. Biomass-fired capacity is not included (except for cases where biomass is added to the coal stream in coal-fired power plants and in the U.S. data) because of limited data availability.

[13]OAPEC includes Saudi Arabia, Iran, Iraq, the United Arab Emirates, Kuwait, and Qatar.

Coal

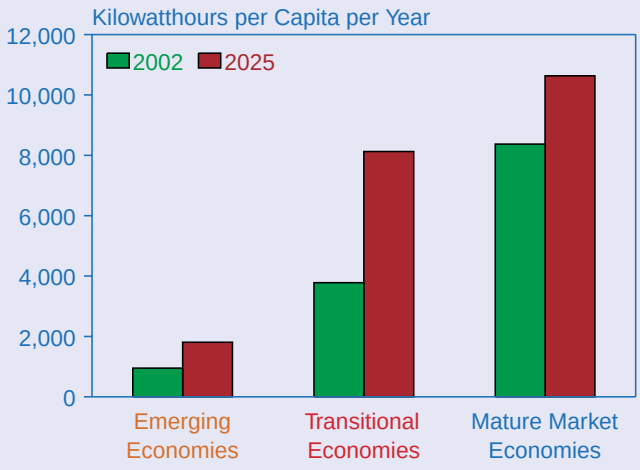
In the *IEO2005* reference case, coal continues to be the dominant fuel for generation of electricity and combined heat and power (district heat).[14] In 2025, coal is projected to fuel 38 percent of the world's electricity generation, compared with a 24-percent share for natural gas. Coal-fired capacity is expected to grow by 1.5 percent per year, from 987 gigawatts in 2002 to 1,403 gigawatts in 2025 (Figure 62). Installed coal-fired capacity, as a share of total world capacity, declines from 30 percent to 26 percent over the forecast.

By country, the United States and China currently are the leaders in terms of installed coal-fired capacity, at 311 and 204 gigawatts, respectively. In China, strong growth in natural-gas-fired capacity is projected to push coal's share down from 65 percent to 52 percent of total

Electricity Consumption per Capita

Net electricity consumption in the world's emerging economies is projected to grow by 149 percent from 2002 to 2025. By that measure, the emerging economies would surpass the mature market economies in terms of total annual electricity consumption; in terms of per capita consumption, however, the emerging economies are expected to continue trailing the mature market economies (see figure below). With the emerging economies expected to account for 82 percent of the world's population in 2025, the projected increase in demand forecast for the region translates to an increase in per capita net electricity consumption from 950 kilowatthours per person in 2002 to 1,807 kilowatthours per person in 2025. Even with this strong growth, per capita consumption for the emerging economies as a whole would remain much lower than that for the mature market economies. Net electricity use per capita in the mature market economies is projected to increase from 8,371 kilowatthours per person in 2002 to 10,632 kilowatthours per person in 2025.

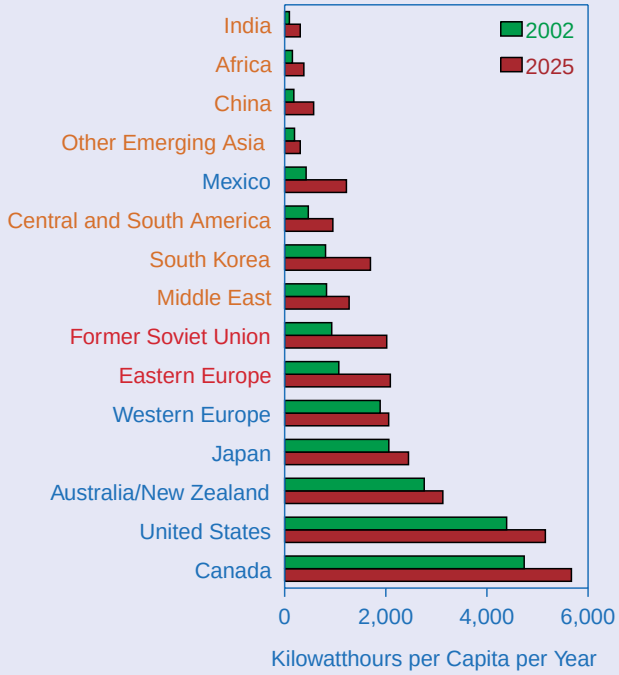
Electricity Consumption per Capita by Region, 2002 and 2025



Sources: **2002:** Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **2025:** EIA, System for the Analysis of Global Energy Markets (2005).

The differences in per capita electricity consumption among the emerging, transitional, and mature market economies are especially stark in the residential sector, which can serve as a proxy for living standards. For example, in the residential sector on a per person basis, Canada and the United States consumed over 24 times more electricity than China in 2002, 29 times more than Africa, and 47 times more than India. Although the differences are expected to narrow over the forecast period, they still would be substantial in 2025, with per capita electricity use in the United States remaining 9 times higher than in China, 14 times higher than in Africa, and 17 times higher than in India (see figure below).

Residential Sector Electricity Consumption per Capita by Country Group, 2002 and 2025



Sources: **2002:** Derived from Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **2025:** EIA, System for the Analysis of Global Energy Markets (2005).

[14]Only in the EE/FSU region is heat a significant portion of the output from central power stations.

generating capacity. In the United States, coal-fired power plants are expected to continue supplying most of the country's electricity through 2025 [*15*]. In 2002, coal-fired plants in the United States (including utilities, independent power producers, and end-use combined heat and power) accounted for 51 percent of all electricity generation. While the output from U.S. coal-fired power plants increases in the forecast, from 1,881 billion kilowatthours in 2002 to 2,890 billion kilowatthours in 2025, their share of total generation decreases slightly, to 50 percent, as a result of a rapid increase in natural-gas-fired generation.

Coal consumption in the United States as a share of fuels used for electricity generation is expected to rise from 52 to 53 percent over the forecast. In terms of installed capacity, coal's share of the total will hold steady at 35 percent. Coal is used for baseload generation, which explains why it accounts for only 35 percent of U.S. capacity but generates more than one-half of the country's electricity.

Western Europe, Eastern Europe, and the FSU all are projected to see declines in coal-fired generating capacity over the forecast period. Not surprisingly, the three regions are also expected to see large increases in installed natural-gas-fired capacity.

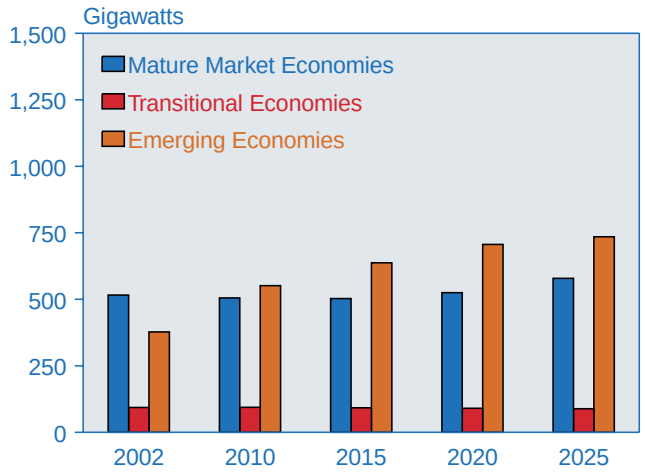
Natural Gas

Additions to natural gas capacity are projected to increase the world's gas-fired generating capacity by approximately 3.9 percent per year from 2002 to 2025 (Figure 63), at a faster rate than projected for any other energy source. Natural-gas-fired capacity is an attractive choice for new power plants because of its fuel efficiency, operating flexibility, rapid deployment, and lower installation costs compared to other technologies. This development represents a major change in the fleet of electricity generation plants. Because of the shorter installation time and lower investment costs for gas-fired combined-cycle generation in comparison to coal, total installed natural gas capacity (combined with oil capacity) is expected to surpass coal-fired installed generation capacity by 2010—1,207 gigawatts versus 1,151 gigawatts. The combined share of natural gas and oil in world installed generating capacity is projected to rise from 36 percent in 2002 to 47 percent in 2025.

In the United States, the electric power sector is projected to account for an ever-larger share of total natural gas demand. About 23 percent of total U.S. natural gas consumption in 2002 was in the electric power sector, and in 2025 its share is projected to be to 31 percent [*16*]. Natural-gas-fired generation capacity is expected to grow more rapidly than capacity using any other energy source from 2002 to 2020. From 2020 to 2025, however, natural gas prices are projected to increase substantially, and as a result coal-fired capacity is expected to lead new additions [*17*].

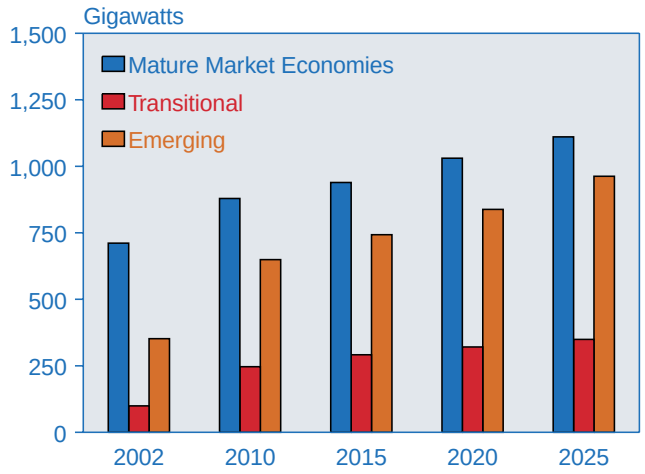
Western Europe, Japan, and Canada are similarly expected to favor natural gas capacity over other fuels for new generating capacity because of lower investment costs and shorter construction times, as well as the fact that gas is an advantageous economic alternative to other fossil fuels. Moreover, these regions have instituted energy policies to limit the use of coal in the

Figure 62. World Coal-Fired Generation Capacity by Region, 2002-2025



Sources: **2002:** Derived from Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2005).

Figure 63. World Natural-Gas- and Oil-Fired Generation Capacity by Region, 2002-2025



Sources: **2002:** Derived from Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2005).

electricity generation sector. With the Kyoto Protocol now in effect, further efforts to reduce greenhouse gas emissions will likely encourage more reliance on natural gas [***18***].

The FSU region, with its access to rich natural gas resources, also increases its reliance on natural gas for electricity generation in the *IEO2005* reference case forecast. Natural gas already provides about 45 percent of the total energy used for electricity generation in the FSU, and the region's reliance on gas-fired generation is projected to increase even further over the next decades, to 55 percent in 2025.

Natural gas consumption in China's electric power sector is projected to increase rapidly from a relatively low total of 0.2 quadrillion Btu in 2002 to 4.3 quadrillion Btu in 2025, at an impressive 14.7-percent average annual growth rate. In comparison, India, South Korea, and the rest of emerging Asia combined are expected to see an increase of 3.7 quadrillion Btu over the period, and natural gas use for electricity generation in the United States is projected to grow by 3.9 quadrillion Btu.

Oil

Relatively little change is expected in oil-fired generation capacity. Oil's share of the world's installed capacity declines over the projection period, from an 8-percent market share in 2002 to 7 percent in 2025. Oil has more value in the transportation sector and in limited applications for distributed diesel-fired generators than in central power plant applications. The only region expected to see a sizable increase in oil-fired electric power capacity is the Middle East, where some new oil-fired capacity is expected to be built. Oil use for electricity generation in the Middle East is expected to increase from 2.1 quadrillion Btu in 2002 to 4.1 quadrillion Btu in 2025.

In recent years, China has shown fairly strong growth in oil-fired electricity generation, because peak electricity demand continues to outpace on-grid electricity generation, and Chinese industry has had to rely on diesel generators to cope with annual summer power shortages. That situation is expected to continue in the short term, but as planned capacity fueled by natural gas, coal, nuclear, and hydropower comes on line and the country's national electricity grid matures, the demand for oil used to generate electricity is expected to moderate.

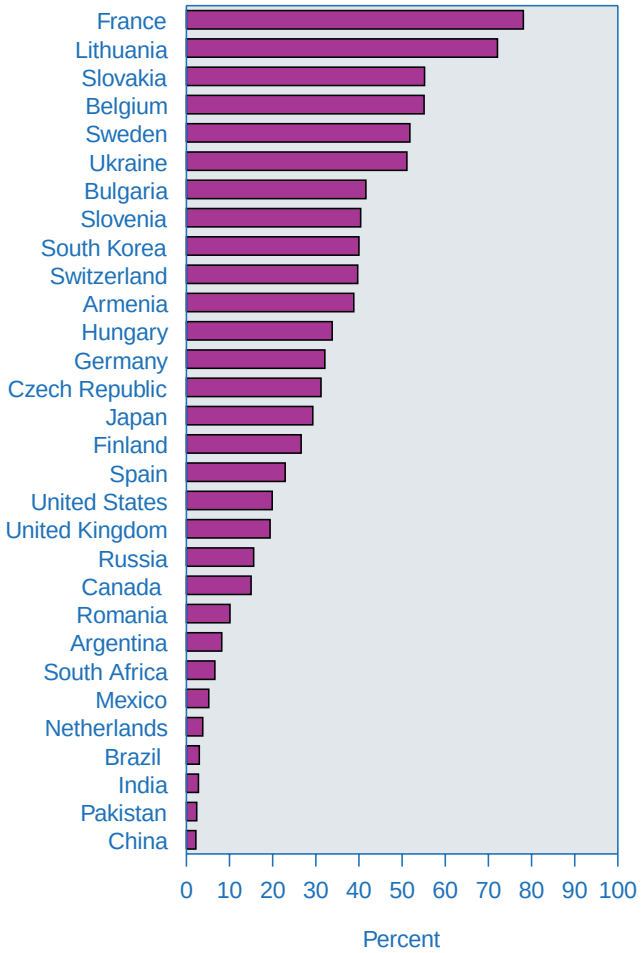
Nuclear Power

In the *IEO2005* reference case, electricity generation from nuclear power plants around the world is projected to increase from 2,560 billion kilowatthours in 2002 to 3,032 billion kilowatthours in 2015 and 3,270 billion kilowatthours in 2025, and the world's nuclear-powered generating capacity is projected to increase from 361 gigawatts in 2002 to 422 gigawatts in 2025. In past editions of the *IEO*, in contrast, declines in nuclear power were projected in the mid-term forecast as a result of expectations that few new reactors would be built and that older reactors would be shut down when they reached the end of their operating lives.

Prospects for nuclear power have improved in recent years, with higher capacity utilization rates reported for many existing nuclear facilities and the expectation that most existing plants in the mature market and transitional economy nations will be granted extensions to their operating lives. Further, higher fossil fuel prices and the entry into force of the Kyoto Protocol are expected to improve prospects for new nuclear power capacity over the forecast period. Nevertheless, nuclear power trends can be difficult to anticipate for a variety of political and social reasons, and considerable uncertainty is associated with nuclear power forecasts (see box on page 72).

Nuclear power is an important source of electricity in many countries of the world. In 2003, 19 countries depended on nuclear power for at least 20 percent of their electricity generation (Figure 64). As of March 2005,

Figure 64. Nuclear Shares of National Electricity Generation, 2004



Source: International Atomic Energy Agency, Reference Data Series 2, "Power Reactor Information System," web site www.iaea.org/programmes/a2/ (June 2005).

How Nuclear Power Could Shape World Electricity Markets: Two Nuclear Power Development Scenarios

Two opposing scenarios of nuclear power development can be used to assess the potential of nuclear power in the electricity markets of the future. In a "strong nuclear power revival" case developed for *IEO2005*, few nuclear plants are retired, and new builds increase the world's total nuclear generating capacity to 570 gigawatts in 2025. In contrast, a "weak nuclear power" case assumes that nuclear power programs, especially in Western Europe and the EE/FSU, are dismantled, few new nuclear power plants are constructed, and installed nuclear power capacity falls to 297 gigawatts in 2025. The *IEO2005* reference case projects an increase in world nuclear capacity, from 361 gigawatts in 2002 to 422 gigawatts in 2025.

In very few instances is the decision to build nuclear power capacity left entirely to corporations or utilities that would base their decisions solely on economics. In general, government policy (with an eye to public opinion) guides the development of nuclear power. The OAPEC oil embargo of 1973-74 led some nations to pursue nuclear power programs aggressively in the 1970s, mostly with strong public support; but subsequent accidents at the Three Mile Island nuclear power plant in the United States in 1979 and Chernobyl in the Soviet Union in 1986 pushed public opinion and national energy policies away from nuclear power. In the United States, rapidly increasing capital costs and repeated construction delays virtually ended construction of nuclear power plants; and in Europe, both before and after the Chernobyl disaster, several European governments, including Italy, Austria, Belgium, Germany, and Sweden announced their intentions to withdraw from the nuclear power arena.

For many years analysts expected social, economic, and political pressures to cause a substantial slowdown of nuclear power expansion in the short term and a decline in nuclear generating capacity in the long term. More recently, however, there has been talk of a "renaissance" in the nuclear power programs of the United States and some European countries, as fossil fuel prices have remained relatively high, and energy security issues, concerns about air pollution and global warming, and the high performance levels of existing nuclear power plants have come to the forefront.[a] On the other hand, a future adverse event involving nuclear power, such as another Chernobyl-sized nuclear power plant accident or a terrorist event involving an attack on a nuclear plant or using processed nuclear materials to commit an act of terrorism, could strengthen negative perceptions of nuclear power.

The table on the opposite page summarizes the projected fuel mix for the world's installed electric power capacity in three cases: the *IEO2005* reference case, strong nuclear power revival case, and weak nuclear power case. With the same macroeconomic assumptions in each of the three cases, it is not surprising that they all project the same total (about 5,500 gigawatts) for world installed electricity capacity in 2025.

Much of the expansion in nuclear generating capacity projected in the strong nuclear power revival case—a total of 148 gigawatts—is in regions with older, more mature nuclear power markets. Many Western European and EE/FSU countries have established nuclear power industries, and they would be capable of staving off the decline in nuclear power capacity projected in the reference case by reversing planned phaseouts of existing nuclear power plants, lengthening operating lives, and constructing new nuclear capacity in response to, for example, concerns about climate change.

In the strong nuclear case, Western Europe's projected nuclear generating capacity in 2025 is 52 gigawatts higher than in the reference, the EE/FSU's is 36 gigawatts higher, and Japan's is 15 gigawatts higher. The *IEO2005* strong nuclear case assumes that emerging economies with nuclear power expansion plans, including China, India, and South Korea, expand the development of nuclear power to the greatest extent possible. Therefore, in the strong nuclear revival case the emerging nations are able to increase their nuclear capacity by adding a combined 37 gigawatts of additional capacity by 2025 relative to the reference case values.

Construction and operation of 148 gigawatts of additional nuclear capacity in 2025 in the strong nuclear revival case would have the greatest impact on the fuel shares of natural gas, oil, and renewables in the fuel mix for world electricity generation (see table). Because Western Europe, the EE/FSU, and Japan all are projected to see declines or minimal growth in coal-fired capacity in the reference case, there is little or no opportunity for new nuclear capacity to displace coal. As a result, the strong nuclear revival case shows declines of 96 gigawatts in natural gas and oil capacity and 32 gigawatts in renewable electricity capacity in 2025 relative to the reference case projections.

In the weak nuclear power case, almost every region loses some nuclear capacity by 2025 relative to the reference case. Only for the Middle East and Mexico, with

(continued on page 73)

[a]S. Taub and J.-L. Wang, *The U.S. Nuclear Power Business: Poised for Expansion?* (Cambridge, MA: Cambridge Energy Research Associates, May 2005), p. 1 (private report).

How Nuclear Power Could Shape World Electricity Markets: Two Nuclear Power Development Scenarios (Continued)

their relatively small nuclear power industries, are the 2025 projections unchanged from those in the reference case.[b] Total world installed nuclear capacity in 2025 is 125 gigawatts lower in the weak nuclear case than in the reference case. Western Europe sheds the largest amount of nuclear capacity in 2025 in the weak nuclear case (50 gigawatts), followed by the EE/FSU (27 gigawatts), emerging Asia (24 gigawatts), and Japan (14 gigawatts).

In emerging Asia, coal-fired capacity makes up for most of the loss of nuclear capacity in the weak nuclear case, with 20 gigawatts of additional coal capacity constructed in China, India, and South Korea compared to the reference case in 2025. The other emerging Asian countries construct an additional 7 gigawatts of natural-gas-fired and oil-fired capacity in the weak nuclear case. In Western Europe, the EE/FSU, and Japan, natural gas, oil, and renewables are used to make up for the loss of nuclear capacity, with 63 gigawatts of additional natural-gas- and oil-fired capacity and 10 gigawatts of additional renewable capacity constructed relative to the reference case projections in 2025.

World Installed Electricity Generation Capacity by Fuel in Three Nuclear Capacity Cases, 2002-2025
(Gigawatts)

Analysis Case and Fuel Type	2002	Projections				Average Annual Percent Change, 2002-2025
		2010	2015	2020	2025	
***IEO2005* Reference Case**						
Natural Gas and Oil	1,207	1,851	2,071	2,304	2,560	3.3
Coal	987	1,151	1,232	1,322	1,403	1.5
Nuclear	361	390	401	411	422	0.7
Renewable	763	927	980	1,036	1,110	1.6
Total	**3,318**	**4,319**	**4,684**	**5,073**	**5,495**	**2.2**
Strong Nuclear Power Revival Case						
Natural Gas and Oil	1,207	1,849	2,041	2,254	2,464	3.2
Coal	987	1,153	1,232	1,320	1,397	1.5
Nuclear	361	395	449	498	570	2.0
Renewable	763	928	970	1,020	1,078	1.5
Total	**3,318**	**4,326**	**4,692**	**5,092**	**5,509**	**2.2**
Weak Nuclear Power Case						
Natural Gas and Oil	1,207	1,865	2,087	2,342	2,626	3.4
Coal	987	1,160	1,245	1,339	1,426	1.6
Nuclear	361	360	357	340	297	-0.8
Renewable	763	934	987	1,050	1,127	1.7
Total	**3,318**	**4,318**	**4,677**	**5,071**	**5,476**	**2.2**

Sources: **2002:** Derived from Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2005).

[b]For the purposes of this analysis, U.S. nuclear capacities were not varied across the nuclear cases. While EIA recognizes that there is potential for increases or decreases in U.S. nuclear power capacity in the future, no analysis has been done to quantify that potential. As a result, U.S. numbers are held constant to levels reported in the *Annual Energy Outlook 2005*.

there were 441 nuclear power reactors in operation around the world, and another 25 were under construction. Five new nuclear power plants began operation in 2004—one each in China, Japan, and Russia and two in Ukraine—and Canada's Bruce 3 reactor was reconnected to the grid. Five nuclear power plants were permanently shut down in 2004—one in Lithuania and four in the United Kingdom.

For the mature market economies, the reference case assumes that, in the long term, retirements of existing plants as they reach the end of their operating lives will not be balanced by the construction of new nuclear power capacity, and there will be a slight decline in installed nuclear capacity toward the end of the forecast. Few new builds are expected in the mature market economies outside of Japan, France, and Finland.

Western Europe's nuclear capacity is projected to drop from 127 gigawatts in 2002 to 115 gigawatts in 2015 and 95 gigawatts in 2025. In Japan, however, nuclear capacity is projected to expand by 9 gigawatts between 2002 and 2025. U.S. nuclear capacity is projected to increase from 99 gigawatts in 2002 to 103 gigawatts in 2025, in part because of the return of the Browns Ferry reactor, scheduled for 2007. Life extensions and higher capacity factors are expected to play a major role in sustaining the U.S. nuclear industry. Thus, despite a declining share of global electricity production, nuclear power is projected to continue in its role as an important source of electric power.

In contrast to the mature market economies, rapid growth in nuclear power capacity is projected for Russia and for the world's emerging economies (Figure 65). The EE/FSU and emerging economies combined are projected to add 42 gigawatts of nuclear capacity between 2002 and 2015 and another 35 gigawatts between 2015 and 2025. Over the forecast period, the largest additions of nuclear capacity are expected in emerging Asia (China, India, and South Korea) and in Russia. China is projected to add 24 gigawatts of nuclear capacity in the *IEO2005* reference case, India 12 gigawatts, South Korea 12 gigawatts, and Russia 14 gigawatts. Among the mature market economies, only Japan is expected to add a sizable amount of nuclear capacity, a total of 9 gigawatts between 2002 and 2025.

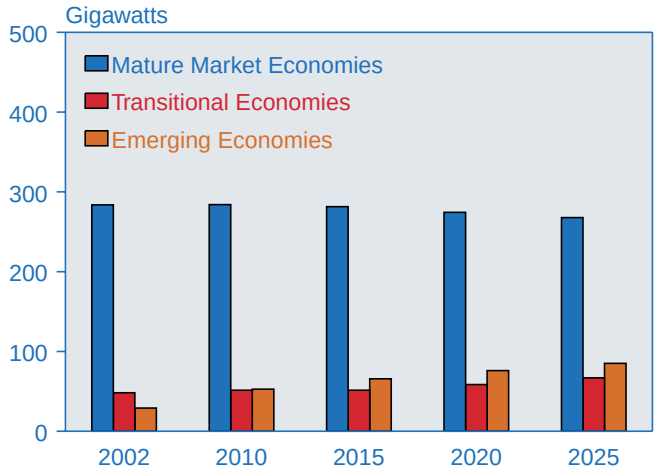
Hydroelectricity and Other Renewables

In the *IEO2005* reference case, moderate growth in the world's consumption of hydroelectricity and other renewable energy resources is projected over the forecast period. Most renewable energy sources are not expected to compete economically with fossil fuels in the mid-term forecast. In the absence of significant government policies, such as those aimed at reducing the impacts of carbon-emitting energy sources on the environment, it will be difficult to extend the use of renewables on a large scale. Worldwide, the use of hydroelectricity and other renewable energy is projected to increase by an average of 1.9 percent per year, from 32.1 quadrillion Btu in 2002 to 42.4 quadrillion Btu in 2015 and 48.9 quadrillion Btu in 2025.

The *IEO2005* projections for hydroelectricity and other renewable energy resources include only on-grid renewables. Non-marketed (noncommercial) biofuels from plant and animal sources are an important source of energy, particularly in the developing world, and the International Energy Agency has estimated that some 2.4 billion people in developing countries depend on traditional biomass for heating and cooking [***19***]. However, because comprehensive data on the use of non-marketed fuels and dispersed renewables (renewable energy consumed on the site of its production, such as solar panels used to heat water) are not available, they are not included in the projections. Both non-marketed fuels and dispersed renewables are considered in formulating end-use energy demands.

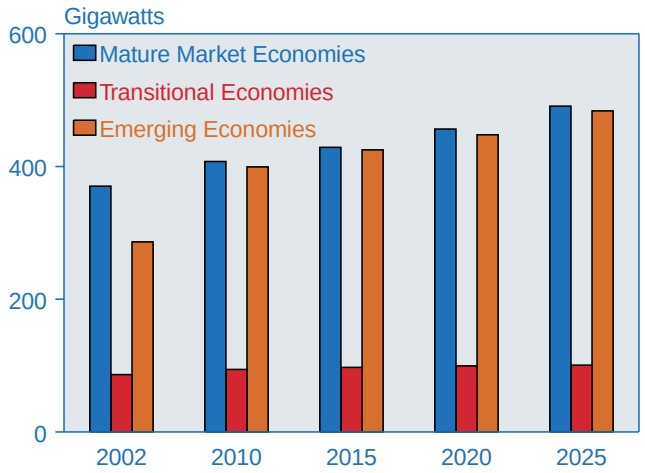
Much of the projected growth in renewable generation is expected to result from the completion of large hydroelectric facilities in the countries with emerging economies (Figure 66), particularly in Asia, where the need to expand electricity production with associated dams and reservoirs often outweighs concerns about environmental impacts and the relocation of populations. China,

Figure 65. World Nuclear Power Generation Capacity by Region, 2002-2025



Sources: **2002:** Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2005).

Figure 66. World Hydroelectric and Other Renewable Generation Capacity by Region, 2002-2025



Sources: **2002:** Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2005).

India, and Laos, among other emerging Asian economies, already are constructing or planning new large-scale hydroelectric facilities. In 2004, India's 1,500-megawatt Nathpa Jhakri project on the Sutlej River in Himachal Pradesh became fully operational [***20***]. In 2005, the World Bank approved financing for the $1.2 billion Nam Theun project in Laos [***21***]. The 1,070-megawatt hydroelectric project in Laos has been the subject of much debate and delay over the past several years, but with financial support from the World Bank and Asia Development Bank the project might come on line as early as 2009 [***22***].China's 11th five-year plan expects 42 gigawatts of additional hydroelectric generating capacity by 2010 [***23***].

Many nations of Central and South America have plans to expand their already well-established hydroelectric resources. Brazil, Peru, and even oil-rich Venezuela have plans to increase hydroelectric capacity over the next decade. Brazil is the largest energy market in Central and South America, and more than 80 percent of its electricity generation comes from hydroelectric sources. As a result, Brazil is especially vulnerable to drought-induced shortages in electricity supply. In general, the nations of Central and South America are not expected to expand hydroelectric resources dramatically but instead are expected to invest in other sources of electricity—particularly natural-gas-fired capacity—that will allow them to diversify electricity supplies and reduce their reliance on hydropower. Brazil had planned to increase the natural gas share of its generation to 12 percent by 2012, but regulatory and price risks have slowed the construction timetables for its planned new gas-fired power plants [***24***].

Hydroelectric capacity outside the emerging economies is not expected to grow substantially. Among the mature market nations, only Canada is expected to construct any sizable hydroelectric projects over the forecast period. An estimated 34,371 megawatts of new hydroelectric capacity currently is under consideration for future development in Canada [***25***]. In the EE/FSU countries, most additions to hydroelectric capacity are expected to come from repair or expansion of existing plants. In the mature market and transitional economies, most hydroelectric resources either have already been developed or lie far from population centers.

Wind power has shown the fastest growth among renewable energy sources in recent years. In many emerging economies, small wind and wind-hybrid installations are effective in bringing electric power to rural areas that cannot be connected to national grids; and among the mature market economies, the growth in wind power has been particularly robust. Western Europe and the United States accounted for nearly 90 percent of all new wind installations in 2003—adding a combined 5,952 megawatts of new wind capacity [***26***]. Germany, Spain, and Denmark all were among the top five wind installers in 2003. Germany added the most wind capacity in 2003, 2,645 megawatts, bringing the country's total installed wind capacity to 14,609 megawatts. In the United States, because the Federal production tax credit for wind plants was not extended until late in 2004, only a little more than 200 megawatts of new wind capacity was added in 2004 [***27***]. In 2005, however, more than 1,000 megawatts of new U.S. wind capacity is expected to enter service.

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